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EFFECT OF RAIL SWITCHING ON INTERMODAL TRANSFER CAPACITY

thesis
K41233

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A research report prepared for the
Construction Engineering and Management Program
in partial fulfillment of requirements for the degree of

Master of Science in Civil Engineering

University of Washington

August 6, 1990

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MONTEREY, CALIFORNIA

ACKNOWLEDGEMENTS

I wish to thank Harry Schaffer and Tom Lee of Burlington Northern for their cooperation and assistance in conducting this research. Also instrumental was Robert H. Stein, who is Burlington Northern Terminal Manager at Chicago Hub Center. Donna Hollar of the Port of Tacoma also provided assistance. Many other Burlington Northern employees connected with the Seattle International Gateway (SIG) facility and the Chicago Hub Center assisted me during this project. I am grateful to all of them.

I also wish to thank Professor Charles Jahren for his role as advisor.

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1. INTRODUCTION

During the 1980's American railroads entered into a new technological era which some consider to be making a far greater change than the conversion from steam to diesel locomotives. This change occurred in the basic elements of freight handling and distribution. The deregulation of intermodal freight and the railroad industry by the Staggers Act caused the railroads to usher in new marketing strategies in order to become more competitive with the trucking industry. For over a century boxcars provided the standard vehicle for transporting general goods. Just after the turn of the century, some railroads began using containers and piggyback trailers for less than car load and special shipments. Gradually more of this intermodal transport was being used by railroads, and by the late seventies, railroads began to reserve entire trains for intermodal traffic.

The smooth operation of an intermodal port is dependent upon many factors, including the efficient operation of the intermodal rail transfer facility. At the present time, it is difficult to plan the development of a new facility or to optimize the operation of an existing one because accurate methods for predicting the capacity and processing time are not available. A computer model which simulates the loading of rail cars

has been developed at the University of Washington (Hollar 1989). However, this model does not simulate the effects of switching the loaded rail cars. The purpose of this project is to develop a computer model which simulates rail switching in a generic intermodal facility.

The computer model will be developed after reviewing the configuration of several rail intermodal facilities. A preliminary selection of parameters to be modeled will be made after a literature review. Examples of parameters to be included are the time required to pull and set rail cars in the loading area, the cycle time for loading a container on a rail car, and the arrival distribution of incoming and outgoing containers. Once developed, the model will be operated and a sensitivity analysis will be conducted to determine which parameters have the greatest influence on intermodal yard capacity.

A modified version of the model should be helpful in answering the following questions:

(1) What is the most efficient use of existing plant and equipment at a given intermodal facility?

(2) Would additional tracks be beneficial?

(3) Would additional loading equipment be beneficial?

(4) Is it most efficient to own the rail switching equipment, or to hire a terminal railroad to switch the yard?

(5) Is on dock rail an advantage?

By being able to simulate the operation of a proposed intermodal yard before large capital investments are made, facility owners and planners will be confident that they have made the right choice. They will be able to design new intermodal yards and improve upon existing ones with greater confidence. Operational improvement can be studied without actually changing the operation.

2. LITERATURE SEARCH

A literature search was conducted to see what, if any, other efforts had been undertaken in this topic area. Sources of information explored included data bases, theses, railroad trade magazines, and other simulation models. It was concluded that in the open literature, no information is available concerning the simulation modeling of intermodal rail switching.

Trade magazines proved to be a valuable source of general information about intermodal facilities and equipment. Several articles have been written recently which describe current trends in intermodal transportation. Topics include the increasing revenue share which intermodal service provides contemporary railroads (Welty 1989; "Intermodal" 1989) and intermodal marketing strategies (Plous 1987; Greenwood 1988; Sorrow 1989; Miller 1989).

Model railroading hobby magazines also provide a wealth of valuable information on this topic. While primarily aimed at hobbyists, these magazines contain large numbers of prototype scale drawings, data, and information (Panza 1987; Casdorph 1988; Panza and Yungkurth 1989).

A computer simulation is a valuable tool for studying and optimizing existing port operations or for developing plans for a new facility. The result of a

simulation is often in the form of graphs and tables. Recently, simulation software packages have been developed which include graphics. These packages provide output in a form which is easily understood by people with non-technical backgrounds.

Railroad operational simulations available include three developed by the Association of American Railroads (AAR) including a Train Operation Simulator (TOS) (Luttrell, et. al. 1983), an Intermodal Equipment Distribution Model (IEDM) developed in 1988 and an Intermodal Terminal Design Model (TSD) developed in 1986. The TOS simulates the performance of diesel-electric locomotives and freight cars over a given track. The model will operate on an IBM PC AT or IBM PS-2. The IEDM is intended to optimize intermodal equipment distribution and is suitable for mainframe operation only. The TSD is a set of four Lotus based models intended for preliminary design investigations of intermodal terminals. This model is not suited for detailed terminal design or simulation. The Train Simulator (1980) is a package similar to the TOS described above. This software will run on an IBM PC and is primarily intended for training personnel in train handling skills. The Princeton Railroad Network Model and Graphic Information System (ALK Associates 1986) simulates the North American rail system and provides graphic display of traffic corridor and shipping data; it is oriented toward railroad

planning, marketing, and operations. This model provides a PC version of the IEDM described above. None of the above models was deemed to have direct application in this study.

In addition, a review was conducted to determine the best simulation software to use for the model. A total of three software packages received serious consideration. The first was SIMAN (Pedgen 1987), and the second was SIMSCRIPT (Fayek 1989). Both of these software packages include animation, both were deemed too complicated for this study owing to the limited time available in which to conduct it. The software chosen for the simulation model was MicroCYCLONE (Halpin 1990). The MicroCYCLONE software does not have graphics capabilities.

3. INTERMODAL EQUIPMENT

Previous efforts to classify intermodal railcars have focussed on the age of a cars' design, dividing them into 1st, 2nd, and 3rd generation cars (McKenzie, North and Smith 1989). These categories refer to the cars' function, including functional conversions made by the railroads and car manufacturers to meet changing market demand. Intermodal cars can be divided into three main categories, which can be further divided into ten sub-categories. Major categories that can be recognized are as follows:

1. CONVENTIONAL PIGGYBACK TRAILER (TOFC) CARS
    * Conversions
    * Contemporary Design, single unit
    * Contemporary design, articulated

2. CONTAINER INTERMODAL (COFC) CARS
    * Conversions
    * Contemporary design single unit, single and double stack
    * Contemporary design, articulated, single stack
    * Contemporary design, articulated, double stack, IBC

* Contemporary design, articulated, double stack, bulkhead

3. DUAL PURPOSE (TOFC/COFC) CARS

* Conversions
* Contemporary designs

The first intermodal cars were simply 40- and 50-foot flat cars. Most were not specially equipped in any way to carry trailers. The trailers were attached in any way possible using chain falls, gripes or come alongs These cars were "circus loaded", which is to say, loaded the same way that Teamsters loaded and unloaded circus wagons a hundred years ago. This is also the origin of the term "team track" for the tracks in an intermodal yard.

Circus loading and unloading is difficult and inefficient. For one thing, the trailers to be unloaded must be oriented with the hitch end toward the unloading ramp. A hostler had to back the tractor onto the car, hitch up the trailer, and then pull it off by moving forward. Temporary, or permanent fold down ramps, known as "bridgeplates", were placed between the cars to permit the tractor-trailers to drive off.

Loading empty flat cars was even trickier; the tractor-trailer hostler had to back the whole rig down

the length of the cars being loaded. This was slow work which required great skill on the part of the hostler.

Advances in hydraulics and metallurgy permitted the development of side loading technology, which became wide spread about 1980. This was a critical step in developing the high speed doublestack trains we know today.

In modern rail car design there are several important factors which must be considered. Final total cost comes to mind first. Converting and refurbishing older cars is generally less expensive than building new cars from the ground up. Two other important considerations are the tare weight and carrying capacity; the lighter a car can be, the better. As one might expect, a stronger car is preferred over a car with less carrying capacity. The type and flexibility of the trailers or containers to be carried are also important. Some specialized designs are needed for specific markets and corridors, but, in general, more flexible designs are more satisfactory. Width and height restrictions, stability, cushioning of the load, and length all relate to train and track dynamics.

The following information represents a summary of the information contained in an article which discussed the subject in detail (Casdorph 1988). For sake of brevity, discussion in this paper will be limited to the contemporary design, articulated, doublestack type cars,

both bulkhead and interbox connector (IBC). These two car types make up the great majority of railcars operating in modern intermodal facilities, and therefore are considered representational for modeling purposes.

CONTAINER INTERMODAL (COFC) RAILCARS

Most intermodal railcars are owned by Trailer Train Company of Chicago, Illinois. Trailer Train is jointly owned by the major U.S. railroads and acts as a leasing agent, providing intermodal railcars to the railroads.

CONTEMPORARY DESIGN, ARTICULATED, DOUBLE STACK CARS

This category has provided the most dramatic illustration of the intermodal revolution. The cars were designed for unit train operation in heavy traffic corridors, but they have also made their way into less dense corridors and even mixed freight trains. Three basic designs have entered service since 1979.

ACF/SP DESIGN, "BULKHEAD" CARS

Prototype double stacks were unveiled by Southern Pacific in 1979 as three-unit cars. They were a conceptual extension of the single-unit double stack designs which were introduced by American Car Foundries (ACF) and Southern Pacific Railway (SP) in 1977. In

1981, following the success of the prototype cars, ACF built 42 five-unit cars for the Southern Pacific. They were initially used for SP Sea-Land Service trains. While no longer in production, these cars led the way for large scale acceptance of other five-unit designs.

BUDD/THRALL DESIGN "IBC" CARS

American President Lines (APL) placed its first five-unit, 40-foot well, double stack cars in service in 1984. These cars were designed by the Budd Company of Philadelphia, Pennsylvania and were built by the Thrall Car Manufacturing Company of Chicago Heights, Illinois. One of the major features of the "Thrall cars" was the use of interbox connectors (IBCs) to load and lock the containers in position. An IBC is a device which is inserted into receptacles at each top corner of a container. A second container is fastened on top of the lower container and locked into position by rotating the IBC. This procedure permits easier and faster loading than the bulkhead system introduced by ACF and SP seven years earlier. The cars are popular with terminal operators for this reason. Additionally, the tare weight of the car is less, permitting a slight increase in capacity.

When doublestack cars were first designed, the standard length of containers was 20 or 40 feet. By 1985, domestic customers had seen the advantages of

containers in new, longer lengths. Eventually, 45- and 48-foot containers were introduced and, in 1988, 53-foot containers appeared. Thrall introduced new cars with well lengths to accommodate the rise in domestic container shipments, including the 45- and 48-foot lengths. (See Appendix A).

GUNDERSON DESIGN "BULKHEAD" CARS

Gunderson Inc. of Portland, Oregon introduced its version of double stack cars later in 1984. Gunderson's cars were similar to the earlier ACF/SP design in that they used bulkheads to secure the containers. The advantage offered by Gunderson was increased security provided by the ability to lock the containers. This was important because, obviously, losing a container from high winds, rough track, or other causes is costly. The main disadvantage of the system is a slightly longer loading time and lesser gross weight capacity. The first production deliveries of these cars were made in early 1985. They were limited in the lengths, and types, of containers they could carry, but soon Gunderson began introducing cars that could hold 20-, 35-, 40-, 45- and 48-foot containers. Since 1985, Gunderson has delivered nearly 4,000 wells. (See Appendix A).

GENERAL CARGO CONTAINERS

The International Standards Organization (ISO) first published a standard for containers in 1973 (Standard 668, Series 1). ISO standards describe over 20 different types of series 1 containers. They can be further divided into two broad groups: (1) general cargo containers and (2) specific cargo containers. General cargo containers are those not intended to carry any particular type of goods. Specific cargo containers are for shipping goods that require temperature control, liquids and gases, dry bulk solids, or items such as automobiles and livestock.

For simplicity, only general cargo containers need be considered for purposes of this study. Within the general cargo container group, the most common is the general purpose container or "dry van." It is totally enclosed and weatherproof, has a rigid roof, floor, side walls and end walls, has doors in at least one end wall, and is suitable for carrying the greatest possible variety of cargo. Other general cargo containers include open top containers and vented containers (passive ventilation).

INTERNATIONAL CONTAINERS

Containers designated Series 1 by ISO are those containers intended for intercontinental use; consequently, these must be built to endure the rigors of shipboard service. ISO standard containers come in various lengths, ranging from 10 to 45 feet. Standard containers are 96 inches wide and either 9 or 9 1/2 feet high, and there are many types. The most common containers on US highways and railroads are 20 and 40 foot ISO Series 1 containers. In 1988, the worldwide fleet of freight containers of all types was estimated to be nearly 5 million units. Most numerous is the "dry van," while the more exotic tank container is less common.

DOMESTIC CONTAINERS

Domestic containers are containers built exclusively for use within the US. As such, they are not required to comply with ISO Series 1 standards. Because of recent changes in ICC regulations permitting longer and heavier trailers on US highways, these now include 45-, 48-, and 53-foot high-cube (102-inch wide by 9 1/2 foot high) dry vans. These general cargo containers are intended for rail and highway service only, although 45-foot boxes built to ISO standards may occasionally be used aboard ship, as all have standard ISO corner castings located at the 40-foot positions on both the top and bottom to

permit stacking with standard 40-foot containers. APC introduced 48-foot containers in the domestic market in 1985 and followed with the first 53-foot containers in 1988 (McKenzie, North and Smith 1989).

CONTAINER HANDLING EQUIPMENT.

In the late 1950's freight containers were introduced into both the international and domestic container transportation networks. Almost immediately, the need for specialized equipment to handle containers became apparent. In those early days of containerization, carriers made do with cranes, hoists and trailers that were not originally designed for containerized cargo. Such "band aid" and temporary fixes did not last long, however. In today's market in which most of the international shipment of non-bulk commodities is accomplished using containers, there are numerous manufacturers of cranes, hoists, and chassis specifically designed to lift and move containers.

DOCKSIDE CRANES

The first containerships had their own cranes onboard for loading and unloading containers. This occurred because most ports in the early 1960's did not have container cranes. As containers increased in size, weight, and numbers, this arrangement became less

satisfactory. The more progressive ports soon acquired suitable dockside cranes specifically designed for the new technology. Steamship lines also began to acquire container handling cranes for their own dock facilities. Today, every major seaport in the world that serves container ships has at least one or more dockside cranes specifically designed for loading and unloading containers.

The first dockside container cranes were the hinged boom type. Normally, the cable was attached to a rectangular lifting frame of approximately the same dimensions as a container. The lifting frame had a container hook suspended from each corner. To lift a container, the four hooks were inserted into the top corner castings on the container. The standard ISO corner casting still has an opening on its side where a hook can be inserted. This type of lifting is rarely done anymore in the United States, but remains common in east Africa, and perhaps other less developed areas.

Gantry cranes have now largely replaced dockside boom cranes. A gantry crane is supported by two vertical trestles and is built much like a bridge. It has a long horizontal boom which extends out over the water or container ships when they are pierside. The cranes are usually rail mounted and move along the dock parallel to the edge. A "spreader bar" has replaced the lifting frame. The "spreader" is suspended from the crane's boom

by the hoisting cables and has "twistlocks" on each of its four corners instead of hooks. The "twistlocks" are inserted into the top corner castings of the container and rotated to lock into place. Once the container is properly engaged by the spreader, it can be lifted. Modern spreaders are telescopic and can adjust to different container lengths. They also have self-leveling systems which help avoid damage to the container's contents during the lift.

Modern container gantry cranes are massive structures. The newest ones are designed to load and unload the latest generation of post-Panamax ships. These newest cranes have a range over 150 feet, a lifting height of over 100 feet and a lifting capacity of greater than 50 tons.

MOBILE CONTAINER HANDLING EQUIPMENT

Many different types of mobile equipment for moving, stacking and lifting containers have been developed since the beginning of the intermodal revolution. All of these machines perform the function of lifting containers on or off railcars, but use different designs and configurations. They are known by a variety of names, including stackers, packers, frontlift trucks, side loaders, straddle carriers, and stacking gantry cranes. Basically, there are two distinct categories of mobile container handling equipment: machines that lift

containers or trailers from the side and machines that lift from the top of, or straddle, them. Within these two categories, there are many variations.

Machines in both categories may have spreaders similar in design and function to those used on dockside gantry cranes to lift containers from the top. They may have grapple arms to lift a container from the bottom. In some cases they may have both, the twist locks on the spreader normally being used for containers and the grapple arms being used for trailers. Forklift trucks can be used to lift containers fitted with forklift pockets. Some of the machines are more versatile and can perform multiple tasks, including stacking containers for storage, and loading both railcars and chassis. Others may only perform a single function such as stacking empty containers.

CHASSIS

A chassis is simply a trailer designed specifically for hauling containers by tractor truck. It is basically a skeletal frame platform equipped with twistlocks to secure the container, a bogie assembly, landing gear, a kingpin, and necessary electrical and pneumatic devices. While most chassis are built for over-the-road use, some, known as bomb carts, are intended strictly for use within container yards and terminals. Highway chassis must have brakes, lights and licenses for use over public roads,

and employ a twistlock container securing system. Yard chassis do not need highway safety equipment and employ simple corner brackets to hold the container in place (McKenzie, North and Smith 1989).

As with other intermodal equipment, chassis come in a variety of sizes and types, including chassis for 20-foot containers only and chassis for 40-foot containers. There are extendable chassis to accommodate different length containers, "Gooseneck" chassis for high cube containers and "Dropframe" chassis for tank containers.

DIESEL-ELECTRIC LOCOMOTIVES

The last required piece of equipment is the diesel-electric switching locomotive. The diesel engine was invented in 1901. By the 1930's, the weight and bulk of the diesel engine could be reduced to the point at which it was feasible to use it as a source of motive power. Today the American diesel-electric locomotive is in its third generation of development (Armstrong 1982).

The basic principle involved is simple. The diesel engine is not mechanically connected to the wheels. Instead, the engine functions as the prime mover for a generator that produces electricity. The electricity is used to operate various electrical loads in the locomotive. Of prime interest are the "traction motors"

that actually power the locomotive's wheels. There are also several auxiliary loads. One of the most important is the air compressor which supplies compressed air for the train's brake lines.

4. SWITCHING RAILCARS

The need for switching arises from several factors. The physical restrictions of the intermodal facility and rail yard are among the most obvious, and, for the most part, these restrictions will determine the yard's capacity. Switching may also be required because of loading philosophies, train and track dynamics, the need to block the train at origin or for the various destinations, and also a number of miscellaneous factors, all of which will be discussed in more detail below.

PHYSICAL RESTRICTIONS

Physical restrictions on growth are probably the most important constraints that managers of intermodal facilities and rail yards face. Intermodal yards are, by their very nature, very likely to be located on a congested urban waterfront where land for expansion is either extremely expensive, or not available at any price. There is ongoing, keen competition for this waterfront property, and there will continue to be so. The various political, socioeconomic, and environmental factors all combine to make development of new waterfront facilities, or expansion of existing ones, difficult or impossible. An intermodal yard in the middle of Nebraska could be huge, but since there are no ships in Nebraska, it would serve no purpose. These restrictions on

expansion and lack of existing space are major factors in determining the particular loading philosophy a yard will employ.

LOADING PHILOSOPHIES

There are two basic loading philosophies that can be identified. Intermodal yards can be operated by the "car assignment" method or the "load lining" method. In load lining, all the containers that enter a yard are unloaded and stored in a specific location by destination. Load lining is efficient in terms of switching and car loading, but takes up a tremendous amount of space- space that many intermodal facilities do not have.

In contrast to load lining, car assignment is a more efficient use of space, but less so in terms of switching and car loading. In car assignment, containers are loaded onto freight cars for shipment as they arrive in the yard. The terminal manager attempts to load an entire car with containers going to just one destination. However, in a pure car assignment system, no containers are stored. If a car must be loaded with containers going to two separate destinations, it is, which means the car must be partially unloaded at the first destination before the car can proceed to the next destination. Partial unloading may also result in a specific car becoming "unqualified," (see next section)

forcing it to remain at its present location until another load can be found for it.

TRAIN AND TRACK DYNAMICS

Because of the risk of derailments, the track and train dynamics over the route of travel must be considered as the train is being made up. Going uphill on a curve, lightly loaded cars that are being pulled (under tension or "draft") will tend to ride up on the inside rail, being pulled to the middle of the curve and derailed by the effective lateral force acting on the stretched cars. Rolling downhill and around a curve, the cars under compression ("buff") will tend to ride up the outside rail and be derailed by the effective lateral force acting on the bunched cars. (See Figures 4.1 and 4.2).

The restrictions regarding qualified cars provide another reason why all wells on the same car cannot always be loaded for the same destination. In order for the car to be fully loaded, it would have to be delayed until enough boxes for that destination arrive, or sent out with empty wells. To wait is undesirable because, in intermodal, speed is of the essence, and to send a car out with empty wells violates the rules at best and can cause a derailment at worst. This is why, at a typical intermodal yard, switch engines are kept busy while managers consider all these various problems. Adding to

the puzzle is the fact that some customers want their cargo shipped and delivered in containers, while others demand trailers. While the actual loading is done by the shipping company at origin, it remains the intermodal terminal manager's problem to find the correct type of car to load the container or trailer aboard.

Burlington Northern Railroad (BN), for example, has mountain restrictions east of Seattle, which were developed to minimize derailments. The restrictions over this line affect (1) the total tonnage of the train, (2) the length and total number of cars that can be in the train, and (3) whether or not cars can be run empty or must be loaded.

BN's major traffic corridor between Seattle and Chicago must cross the Cascade Mountain range. This line has a maximum grade of 2.2% and many tight curves. Specific restrictions imposed are that the first 25 cars of all trains must be "qualified"; that is, conventional cars must be loaded with two trailers or containers on each car, and a doublestack car must have at least one container in each well. A train of less than 5500 tons can be pulled with locomotives on the head end only, and trains which exceed this limit, but are less than 7500 tons and under 7700 feet long (about 25 contemporary design, articulated intermodal cars), must have helper locomotives cut into the middle of the train. An all-conventional intermodal car train may total no more than

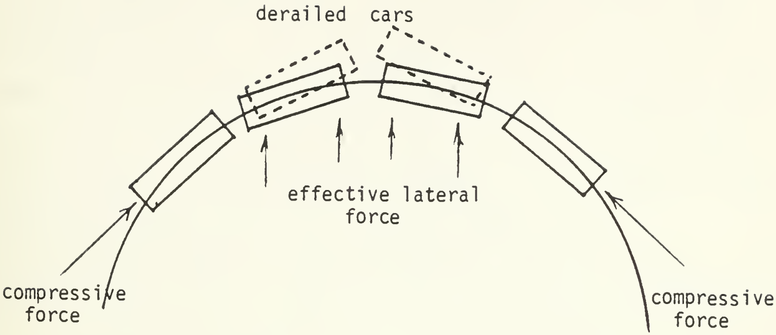

Figure 4.1: Cars going downhill on a curve, under compression

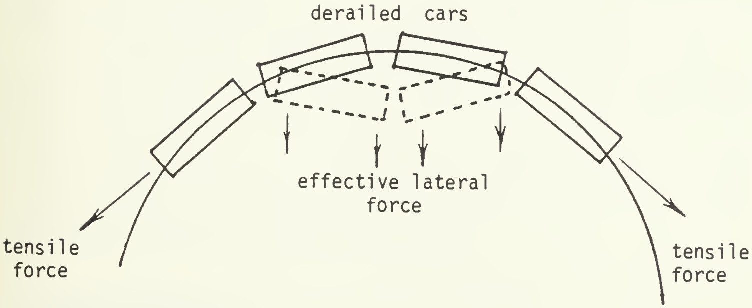

Figure 4.2: Cars going uphill on a curve, under tension

45 cars (about 4050 feet). In a mixed conventional and doublestack train, the total weight must be less than 4800 tons, all doublestacks must be at the head end, and all conventional cars at the rear. A solid doublestack train cannot run empty wells anywhere in the train. Most other railroads, especially in the west, face restrictions similar to those of Burlington Northern.

BLOCKING THE TRAIN

Inevitably, trains must be switched at both origin and destination. However, trains are always blocked at their origin by destination. In other words, they must be arranged so that all the cars going to the same destination are placed together in the train. This makes it easier for the train crew to set out and pick up cars enroute. It is common practice for the cars to be set out first to be placed at the beginning of the train, but it should be noted that, as previously stated, rules governing placement of "qualified" cars take precedence above blocking by destination. As an example, there are commonly five to seven blocks for each train departing Seattle on the Burlington Northern.

OUTSIDE AGENCIES

Other agencies influence intermodal operations, often making it difficult or impossible to predict accurately how many and what type of containers or

trailers will arrive on any given day. These agencies include but are not limited to US Customs, which may have to delay a particular container or a whole shipment until it can be properly inspected. The labor agreements that have been negotiated with the Long Shoremen and Teamsters Unions often include shut down time for breaks and restrictions on the hours of work.

In intermodal yards, cars are generally set with double stack cars on one track and conventional intermodal cars on another track. On any given day, it is impossible to predict the number of containers that will go to a particular destination. Therefore, it is impossible to preassign cars by destination within a yard and to always load a car with containers or trailers going to the same destination. Thus, the requirement for switching is inevitable.

SWITCHING PRINCIPLES

Switching is considered to be a necessary evil in operating a railroad. The switching crew normally includes an engineer, who operates the locomotive; one or more brakemen, who handle the chores on the ground such as coupling and uncoupling the cars and throwing switches; and a switch foreman. The brakemen are often required to climb on and jump off slowly moving rolling stock, as they ride on the cars in order to travel between locations of successive tasks.

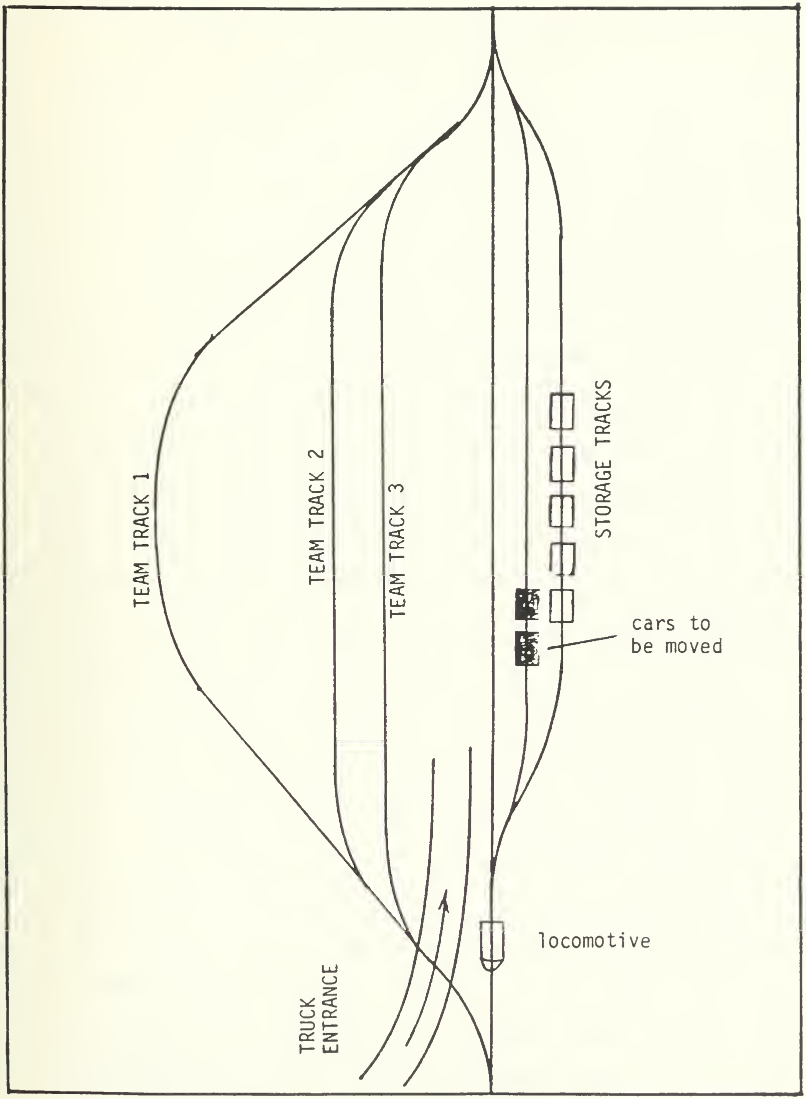

Figure 4.3: Cars on a storage track in a rail yard.

For sake of illustration, consider a cut of cars sitting on a storage track in a yard. This cut must be moved to a team track in an intermodal yard and then loaded with containers. This situation is illustrated in Figure 4.3. The first person in the process is the terminal manager, who is in charge of the terminal and knows the day's scheduled ship and train arrivals and departures. The terminal manager informs the train master that an empty car is needed for loading. The Trainmaster is the person in overall charge of the yard tracks and is in radio contact with the individual locomotives through other personnel in the yard tower or office. Next, a switching crew is called on the radio and is given the location and equipment identification number of the car to be moved. While the locomotive is being operated to the car's location by the engineer, the brakeman is not needed on the ground and usually rides in the locomotive cab, perhaps helping the engineer observe any conflicting traffic or other problems. When the locomotive reaches the car in question, the engineer approaches it slowly and the brakeman swings off the locomotive and walks to the car. Using hand signals or, preferably, hand held two-way radios, the brakeman guides the engineer as the locomotive moves closer to the car, stopping when the knuckles of the couplers engage and lock. Now the brakeman must go between the locomotive and car and connect the air hoses or "glad hands", which

are part of the braking system (as explained in the next paragraph). There are valves known as angle cocks on all the air hoses; the brakeman confirms that the angle cocks on the two hoses he just connected are both open and that the valve on the other end of the car is closed.

Modern freight cars are equipped with two kinds of brakes: air brakes for primary use while in a train, and hand brakes which are used in spotting a car by itself on a siding when train air is not available. When switching light loads, such as a single box car, often the train air lines are not connected; consequently, the air brakes are not used. However, the five well articulated type cars which are used in container loading are considered too heavy for a small switch engine to move safely without the use of air brakes. The air brakes are held off by air pressure; this is a safety design so that if air pressure is lost at any time, say because a coupler brakes and the train is parted, then the loss of the air pressure will cause the brakes to be applied. The air hose is connected from the switch engine to the car, and the air compressor in the switch engine pumps to bring the air pressure up to an acceptable level in the train's braking system. If the air hose valve at the other end of the car is open by mistake, then the train line will not hold air pressure and the brakeman will have to walk to the other end of the car to close the valve. Since many modern articulated cars can be over 300 feet long,

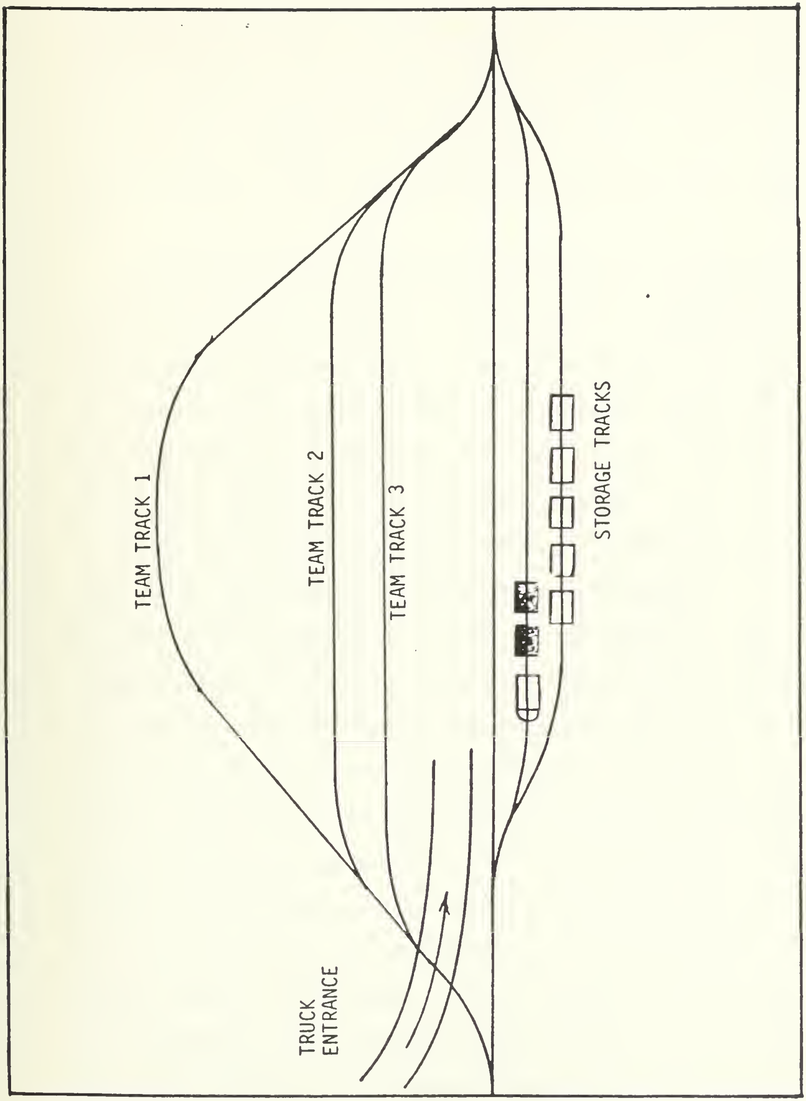

Figure 4.4: Locomotive and cars ready to move.

the walk can be quite time consuming. With both valves closed, the air pressure is increased, and the brakes on the car are released. The locomotive and car are now ready to move. This situation is illustrated in Figure 4.4.

The brakeman may climb aboard either the locomotive or the car for the ride to the team track. Depending on the distance, this may take several minutes. The speed for trains within yard limits is typically restricted. From the author's observations, five mph is a typical speed for operation in an intermodal yard.

Once the locomotive and cut of cars arrives at the team track, the engineer slows the train, again permitting the brakeman to swing to the ground. The brakeman will probably have to throw one or more switches in order to align the tracks so that the car can be placed or spotted on the correct track. This done, he signals the engineer to proceed via radio or hand signal. The car is slowly pushed into the correct position. This situation is illustrated in Figure 4.5. The locomotive must now be uncoupled from the cars. The brakeman may go between the cars and close both air valves: one on the car, the other on the locomotive air hose. If this is done, the brakes are not applied and the car is free to roll after the locomotive leaves. Alternatively, if one of the valves is left open, the air will escape from the air lines on the car and the brakes will automatically

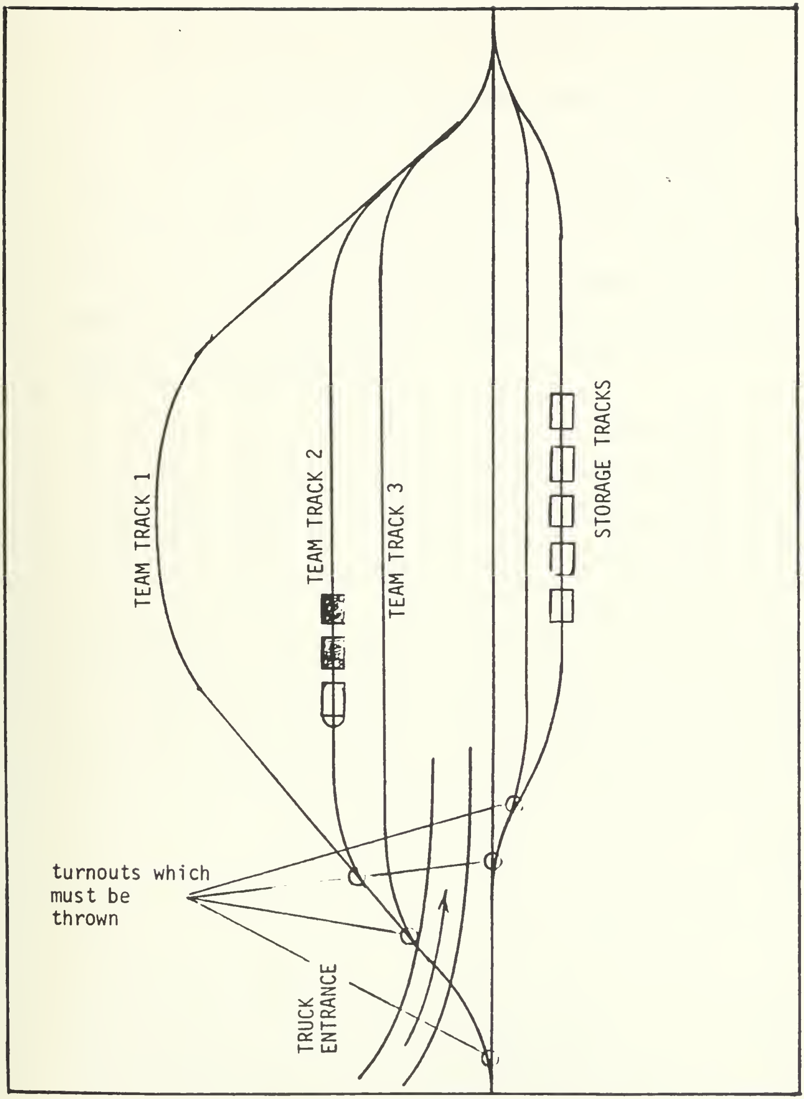

Figure 4.5: Locomotive and cars ready for uncoupling.

set. After both air valves are closed, the brakeman steps back out alongside the track and pulls a lever which allows the coupler to open. Now the brakeman signals the engineer, who backs the locomotive away. The air hoses separate without assistance. The hand brake wheel is then turned to actuate a secondary mechanical braking system that serves the same function as a parking brake for an automobile.

5. METHODOLOGY AND RESULTS

The investigation into operation of intermodal facilities consisted of a series of on site interviews followed by the development of a computer simulation. This chapter describes the methods and techniques used in developing the study. A discussion of the site visits is presented first, followed by a general discussion of simulation modeling. A detailed discussion of MicroCYCLONE modeling methods is the final part of this chapter.

INTERVIEWS

Familiarity with intermodal switching is required before one can develop a meaningful computer model. To facilitate this, a group of standard questions was developed in order to ensure that all major points were discussed. The interviews also served the purpose of ensuring that the author would become familiar with the terminology and concepts associated with intermodal terminal operations. The questions and a brief summary of results are contained in Appendix B.

The criteria for choosing sites to visit were two fold. First, it would be desirable to visit sites in as many different geographic regions of the United States as possible. Second, it would be desirable to visit terminals operated by as many different railroads as

possible. It was hoped these criteria would insure that information gathered would not contain proprietary or geographical limitations.

The following sites were visited:

Burlington Northern Seattle International Gateway, Seattle, Washington.

Burlington Northern Balmer Yard, Seattle, Washington.

Southern Pacific Intermodal Terminal, Oakland, California.

Atchison, Topeka and Santa Fe Richmond Yard, Richmond, California.

Burlington Northern Chicago International Gateway, Cicero, Illinois.

SIMULATION

A simulation is a mathematical model of some historical event or activity which attempts to reproduce the most important aspects of the event or activity being in question, often in order to study and make predictions about future events. A previous study of intermodal operations (Hollar 1989) has suggested dividing these

aspects into two categories, physical constraints and operational constraints. Physical constraints on a model of rail switching in an intermodal facility would include the physical size of the rail cars, the speed at which they are moved, the number of tracks in the facility, and the time required for personnel to carry out tasks like throwing a switch or coupling and uncoupling cars. Operational constraints include items like labor agreements and industry rules and regulations.

Simulation models rely heavily on the laws of mathematical probability to simulate real life occurrences. Once a model is developed, comparison of results to existing historical data must be made. In game theory this is referred to as play testing, and in simulation models it might best be described as authenticating or verifying the results. Following an initial verification, the model is fine tuned. After some number of iterations of comparison with historical data and fine tuning, the model is considered capable of reasonable predictions.

When making a model with the MicroCYCLONE software (Halpin 1989), one breaks the intermodal terminal operation is broken down into component activities, operations, processes, and work tasks.

Work tasks are fundamental field actions, and generally involve only a single person or crew. Work tasks in an intermodal yard would include a brakeman

coupling and uncoupling cars and throwing switches. The engineer operating the locomotive's air compressor to pressurize the train's air line is another example of a work task. A worker operating a hoist and lifting a container from a chassis to a car well is still another example.

A process is a logical collection of work tasks. Processes usually involve more than just a single trade. In an intermodal facility, the movement of a cut of cars (loaded or empty) would represent a process.

An operation is a logical collection of processes. An operation in an intermodal facility would be the movement of several cuts of cars through the yard. The operation would result in the making up of a train of intermodal cars ready to depart the facility.

An activity is the attainment of a physical segment of some whole. In the intermodal facility, departure of a train would signify the completion of a full cycle.

The final model must be logical sequence of work tasks collected into processes, further collected into operations. The completion of each cycle or activity will be indicated by a single numerical increase in the program counter. (See function node, described below).

In order to make models with the MicroCYCLONE program, a network is constructed with a string of logic elements called nodes. There are four basic elements in

the MicroCYCLONE language: normal, queue, combination and function. (See legend on Figure 5.1).

A normal node is the simplest. It allows the modeler to specify a time duration for an event. In contrast to the combination node (described below) the normal node does not require that the elements preceding it be specified.

A queue node is an element which represents a place in the network where resources are detained, or "queue" up. A special function can be added to a queue node, called a generate function. The generate function is used when resources arrive in packages. For instance, when one articulated intermodal car arrives at a facility, it consists of ten places for containers.

The combination node must be preceded by queue nodes. The combination node requires that resources be available in each of the queues preceding it before the process can proceed through it.

There are two types of function nodes available in MicroCYCLONE. The first is the counter node, which is inserted into a network in order to measure production output. The second is the consolidate function, which is the opposite of the generate function described above. The consolidate function can be employed when a modeler wants to collect resources, for example, when ten containers are collected on one modern articulated intermodal car.

BASIC COMPUTER MODEL (SINGLE TRACK FACILITY)

Owing to the complex nature of an intermodal operation, the approach was to develop the model as a series of modules. Each module would represent an increase in complexity over the previous. Experience with other modeling attempts (Hollar 1989) supports this approach.

The initial computer model was developed after reviewing the configuration of the rail intermodal facilities visited during the on-site interviews, and it is intended to represent a generic intermodal facility. Parameters required for a basic model include the time required to pull and set cuts of cars on a track as described in chapter 4, the cycle time for loading a container on a rail car, and the arrival distribution of incoming containers. A logic diagram of the model is shown in Figure 5.1, and the MicroCYCLONE code is shown in Appendix C.

The time required to accomplish the process of pulling and setting a cut of cars on a track is actually the sum of the time required to perform several individual work tasks. The work tasks include coupling, pumping air, and pulling the loaded cut of cars out of the tracks, throwing a turnout and pushing them into a storage track. The engine then uncouples and moves to a string of empty cars in the storage yard. These cars are

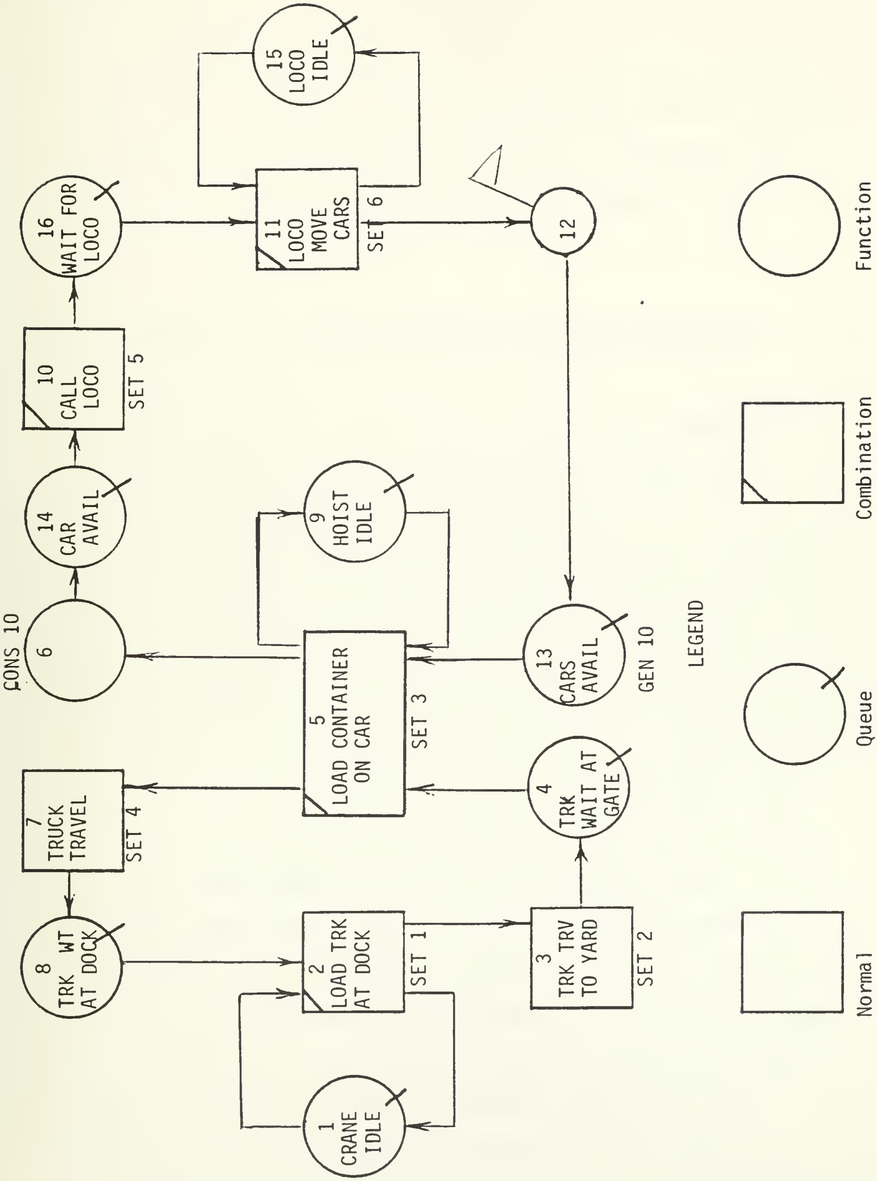

Figure 5.1: Logic network for initial computer model of single track intermodal facility.

pulled out of the storage yard and pushed into the team track. The locomotive then uncouples and leaves, thereby becoming available to repeat the cycle. Estimated time required to perform each work task is shown in Table 5.1.

TABLE 5.1: TIME REQUIRED TO PERFORM SWITCHING

WORK TASK	TIME (min)
Pull cars 4000ft @ 5mph, perform twice	9
Push cars 4000ft @ 5mph, perform twice	9
Throw turnout, perform twice	1
Couple, twice	1
Pump air, twice	3
Uncouple, twice	1
Total	24

The Basic computer model is composed of two processes which are joined by one work task through a combination node. The first process delivers containers from the dock and consists of nodes 1, 2, 3, 4, 5, 7 and 8 in Figure 5.1. The second process switches empty and loaded railcars from the intermodal facility to the storage tracks. It consists of nodes 5, 6, 9, 10, 11, 12, 13, 14, 15 and 16 in Figure 5.1. The program code for the model is contained in Appendix C.

Node 2 represents a dock crane loading a container onto a truck for transport to the rail facility. It is a combination node because it requires resources to be available before it can be accomplished, namely, a crane at node 1 and an empty truck at node 8. The time required to load the truck is represented by the values in SET 1. These values specify a minimum and maximum value between which times are assumed to be uniformly distributed. Table 5.2 illustrates all the SET values used in the model.

The loaded truck then proceeds to the rail facility through node 3, with travel time as specified in SET 2. The truck arrives and waits at the gate represented at node 4. Node 5 is a combination node which requires a loaded truck at node 4, an empty rail car at node 13 and an idle hoist at node 9. At node 5 the container is shifted from the truck to the rail car, requiring time specified in SET 3. The empty truck then proceeds through nodes 7 and 8 back to the dock for reloading, with travel time stated in SET 4.

Node 6 is a consolidate 10 function. This function requires 10 containers be loaded onto a rail car, fully loading one articulated double stack car. This done, a locomotive is called at node 10. The time required to call the locomotive is specified in SET 5 (see Table 5.2) and is contingent upon a loaded rail car being available

in node 14. The car (loaded with 10 containers) then waits for the locomotive at node 16.

Node 11 is another combination which requires that a loaded railcar be waiting at node 16 and that a locomotive be waiting at node 15. SET 6 is the time required for a locomotive to retrieve the loaded car and replace it with an empty car, as determined in Table 5.1.

The empty cars are placed at node 13, making them available for the combination node 5. The generate 10 at node 13 represents the fact that an individual modern intermodal railcar can carry 10 individual containers. On the way, Node 12 counts off one cycle which accumulates output in terms of loaded railcars per hour of operation.

TABLE 5.2: ASSUMED SET TIMES IN MODEL

SET VALUE	TIME(min)
SET 1	1.25 to 1.75
SET 2	2.00 to 4.00
SET 3	1.25 to 1.75
SET 4	2.00 to 4.00
SET 5	10.00 to 15.00
SET 6	20.00 to 30.00

The truck travel times have deliberately been set so that they are unrealistically short, since the model is intended to study the rail movement and not the movement of the trucks. Keeping the truck travel time to a minimum facilitates the examination of a larger number of rail movement cycles.

Lines 19 through 27 of the model (see Appendix 3) represent the resource input. It was assumed that two cranes would be working at pier side, that two hoists would be working in the intermodal facility, and that two locomotives and 6 cars (30 wells) would be available. The number of cars in a string could be modified by increasing the "generate" number by any multiple of ten, that is, 20 wells would represent two cars, 50 wells five cars, and so on.

Another significant item in the model is the total number of trucks in the cycle. Lines 21 and 22 of Appendix C show that a total of 20 trucks are assumed to be working. A study was conducted to determine how sensitive the model is to the number of trucks present. The basic model shown in Figure 5.1 resulted in production of 4.6 units/hour, which physically represents 4.6 loaded railcars in 1 hour. This value was taken as a benchmark and further comparisons were made against it. It was assumed that there should be enough trucks in the cycle so that the container hoists are not waiting in the intermodal facility for trucks to arrive; that is, it is

desirable to have the trucks waiting for the loader. The model was run with 2, 20, and 200 trucks to determine if the level of production was affected. Results are shown in Table 5.3.

TABLE 5.3: PRODUCTION OUTPUT WITH VARIOUS NUMBERS OF TRUCKS

NUMBER OF TRUCKS	PRODUCTION	% DIFFERENCE
2 trucks (1 at 4, 1 at 8)	3.0 units/hr	35
20 trucks (10 at 4, 10 at 8)	4.6 units/hr	0
200 trucks (100 at 4, 100 at 8)	4.6 units/hr	0

It is apparent from Table 5.3 that 20 trucks are sufficient to prevent the hoists from having to wait for containers to arrive.

The next test performed on the model was intended to determine how its sensitivity to the type of probability distribution defined in lines 28 through 34 of Appendix C. The many types of probability distributions are covered extensively by numerous authors and are outside the scope of this paper. MicroCYCLONE permits the programer to choose between the five different distributions shown in Table 5.4. As previously stated, the parameters defined in Table 5.2 resulted in an output

of 4.6 units/hour, which was taken as a bench mark. The specific type of distribution was varied as shown in table 5.4 and results noted.

TABLE 5.4: PRODUCTION OUTPUT WITH VARIOUS DISTRIBUTIONS

DISTRIBUTION	PRODUCTION	% DIFFERENCE
Uniform (as shown in App. C)	4.6 units/hr	0.0
Deterministic	3.4 units/hr	26.0
Triangular 1 △	4.6 units/hr	0.0
Triangular 2 ◺	4.3 units/hr	6.5
Triangular 3 ◿	4.9 units/hr	6.5
Beta	4.1 units/hr	10.8
Normal	4.1 units/hr	10.8

From the results shown in Table 5.4, it was concluded that the uniform distribution as defined was a reasonable approximation of reality. To further refine the model, future researchers should consider collection of actual data in the field to physically verify the distribution.

The final test performed on the model was to determine how sensitive it was to variations in the uniform distribution. The uniformly distributed parameters were modified as shown in Table 5.5. During each test the parameters not modified were returned to

those shown in Table 5.2. As before, the results were compared against the value of 4.6 units/hour output.

TABLE 5.5: PRODUCTION OUTPUT WITH VARIOUS UNIFORM DISTRIBUTIONS

UNIFORM RANGE (changed to)		PRODUCTION	% DIFFERENCE
Loco move cars	40.00 to 60.00	2.0 units/hr	56.5
Call loco	20.00 to 30.00	4.6 units/hr	0.0
Truck travel	4.00 to 8.00	4.6 units/hr	0.0
Hoist time	2.50 to 3.50	4.5 units/hr	2.2

From Table 5.5 it is apparent that the most critical parameter in the model is that of the time consumed by the locomotive in moving the cars.

ADVANCED COMPUTER MODEL (3 TRACK FACILITY)

A network logic diagram of a more advanced computer model is presented with program code in Appendix D. This model is a generic representation of a three track intermodal facility, and was developed on the principle of producing ever-increasing degrees of complication in the model logic. Close examination will reveal that it is in reality the network logic of the single track

facility reproduced in triplicate. No results were obtained from this model.

ADVANCED MODEL (SINGLE TRACK FACILITY) WITH ENTRANCE INTERDICTION

Appendix E contains the network logic diagram and program code for a single track intermodal facility which has the added provision of simulating the effect of the locomotive and rail cars interdicting the truck entrance each time a switching move is conducted. This model was developed because it would be desirable to determine the loss of production associated with this phenomenon.. Note that program steps 17 through 26 have been added to the basic single track facility model in order to accomplish the desired effect. Table 5.6 shows the results obtained from this model compared with the results of the basic single track facility model.

TABLE 5.6: COMPARISON OF PRODUCTION FROM SINGLE TRACK FACILITY MODEL VS. PRODUCTION FROM SINGLE TRACK FACILITY WITH TRUCK ENTRANCE INTERDICTION

MODEL	PRODUCTION	% DIFFERENCE
Basic single track facility	4.6 u/hr	0.0
Single track with entrance interdiction	4.5 u/hr	2.2

There are several problems evident in this model. Because node 26 is a combination, it must be preceded by queue nodes. (See Chapter 5). Consequently, nodes 4, 18, 20, 22 and 24 must be queues. Since there must be a resource in each queue before the "crossing idle" node 26 is active, this model in effect states that there must be four locomotives in the crossing in order for it to be idle. This, obviously, is nonsense. A suggestion for further study would be to change nodes 4, 18, 20, 22 and 24 to combination nodes and node 26 to a queue. Such a model may produce reasonable results.

6. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

It was an objective of this study to produce a computer model of rail switching in a hypothetical intermodal facility. Such a model would enable facility designers and planners to study the effects of various modifications before committing large capital investments. The model developed is generic and does not represent any specific facility. However, it is possible to modify the model to represent a specific facility.

Several conclusions can be drawn from this effort:

The model produces results that are not sensitive to a specific distribution.

The model will be useful in determining what data needs to be collected. Data such as the time needed to couple, uncouple, pump air and throw turnouts may be found to be non-site specific. Data such as truck travel time to and from the dock, and time required for the locomotive to push and pull cars will be site specific owing to variations in the distances involved.

The model will be useful to facility managers who wish to play "what if" games.

Developing computer models is difficult and time consuming. It took much longer to develop the model than was anticipated, probably because learning new software is very frustrating and time consuming.

The intermodal industry is very dynamic, and intermodal facility managers are extremely busy people.

In addition, several problems were identified that seem to be common to almost every intermodal facility:

The facilities' truck entrance is interdicted by the trains while they are switching cars.

Trains do not always arrive at the facility as scheduled. This is a constant source of problems for the facility managers, yet one which they are helpless to correct.

Sometimes intermodal trains include non-intermodal freight cars. This makes extra switching necessary at the destination.

Facility managers are frustrated by the many large number of different types and sizes of intermodal cars and containers in service today.

Several problems were encountered in using MicroCYCLONE:

The software is very platform specific; the author could only run it on an IBM PC/AT. This can be a serious inconvenience.

The author encountered several bugs in the program. The program often crashes and returns the user to the DOS without warning or explanation. This is a source of frustration.

There is no documentation regarding the error messages. A common error message is "THERE IS AN UNIDENTIFIED PROBLEM" followed by a crash back to the DOS. A student will find this extremely frustrating.

There is no large network of MicroCYCLONE users at the University of Washington, which makes it very difficult to find help for even simple questions. The authors of the software provided help by phone,

which was greatly appreciated, but there is no substitute for face to face assistance.

RECOMMENDATIONS

Having completed this study, I wish to make the following recommendations:

A dedicated data collection effort should be undertaken to gather more accurate information on the most sensitive parameters represented in the models. Once the accuracy of the parameters is improved, further simulation runs should be conducted to provide more accurate information concerning the capacity and throughput times of a typical intermodal facility. Gathering data for the site specific parameters will permit study of a specific facility

In cases where the results are distribution sensitive, the actual type of distribution should be verified by collecting a large amount of data in the field.

The intermodal industry should make an effort to standardize the types of railcars and the size and types of containers in service.

Studies of intermodal facilities should include, but not be limited to, models of this type. Planners and designers should also consider other site specific aspects such as weather, topography, geology and other pertinent factors.

One of the greatest difficulties encountered in this research was developing the model itself. One advantage of the MicroCYCLONE software was that it appears to be less complex. Because it does not include a graphics package, the student is encouraged to concentrate on the modeling aspects of the program. Despite this apparent simplicity, it took much longer to develop the initial model than originally estimated. Future researchers should consider the following recommendations when choosing software for further work on this subject:

Because of the difficulties explained above, success with MicroCYCLONE is proportional to previous experience with personal computers. It is not a good choice unless the researcher is very proficient in the use of computers, or has a strong local support network.

MicroCYCLONE users should network and exchange information. The MicroCYCLONE newsletter, which is published by Purdue University, might be a good starting point.

The authors of the MicroCYCLONE software should publish documentation which explains the error messages which are generated by the program.

As a final word, I would like to say that I believe the intermodal industry will continue to grow in the 1990's, perhaps even faster than it did in the 1980's. Funds for public works projects are becoming more and more difficult to obtain, and the infrastructure of the United States is deteriorating. Eventually, the nation's highways may no longer be available to trucking companies for cross country hauls. This will force a realignment of our national transportation economy and push rail intermodal services to the forefront of the transportation industry.

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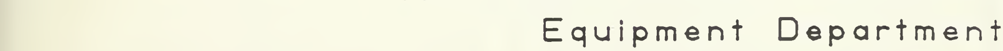
LOADING CAPABILITIES DTTX DOUBLE STACK CONTAINER CARS

TRAILER TRAIN COMPANY
Equipment Department
MAY 1, 1989



TRAILER TRAIN COMPANY CURRENTLY HAS APPROXIMATELY 1950 DTTX CARS (9750 WELLS) IN SERVICE OR SCHEDULED TO BE BUILT.

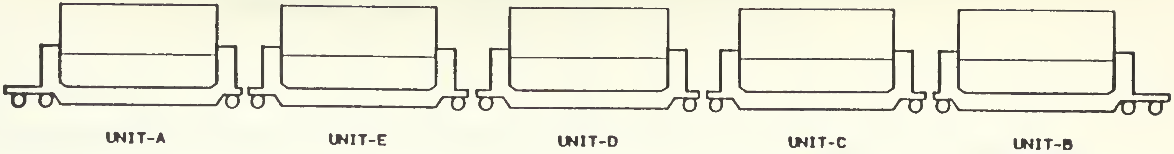
THE LOADING POSSIBILITIES FOR THESE CARS DIFFER WIDELY FROM CAR CLASS TO CAR CLASS AND FROM BUILDER TO BUILDER.

IN ORDER TO PROVIDE A READY REFERENCE, WE HAVE PREPARED THE FOLLOWING LOADING CAPABILITIES CHARTS WITH SUCH DATA AS BUILT DATE, WELL CAPACITY, LIGHT WEIGHT AND LOADING CAPABILITIES FOR EACH CAR CLASS AND EACH CAR SERIES.

THESE CHARTS ARE ARRANGED ALPHABETICALLY BY CAR BUILDER AND NUMERICALLY BY CAR NUMBER.

PERIODIC UPDATING WILL BE DONE TO INCLUDE ADDITIONAL CARS ADDED TO THE TRAILER TRAIN FLEET.

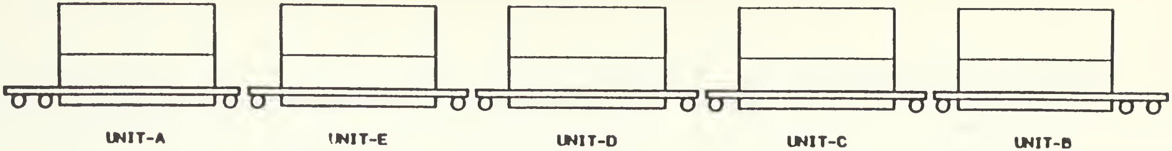
DTTX
DOUBLE STACK CONTAINER CAR - BULKHEAD TYPE
(GUNDERSON 100-TON DESIGN)



CAR Nos.	CAR CLASS	LOAD LIMIT PER WELL	LOWER POSITION WELL CAPABILITIES					UPPER POSITION WELL CAPABILITIES				
			"A" UNIT	"E" UNIT	"D" UNIT	"C" UNIT	"B" UNIT	"A" UNIT	"E" UNIT	"D" UNIT	"C" UNIT	"B" UNIT
63000-63099	GWG50	98000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63100-63129	GWG50A	97000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63130-63174	GWG50B	98000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63175-63178	GWG50C	98000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63179-63198	GWG50D	96000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63199-63200	GWG50E	96000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63201-63235	GWG50F	97000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63236-63265	GWG50E	97000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63266-63285	GWG50F	97000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63286-63300	GWG50E	96000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63301-63310	GWG50G	94500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63311-63320	GWG50H	96000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63321-63330	GWG50E	96000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63331-63337	GWG50J	96000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
63338-63342	GWG50G	94500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

DTTX

DOUBLE STACK CONTAINER CAR-IBC TYPE
(GUNDERSON 125-TON DESIGN)



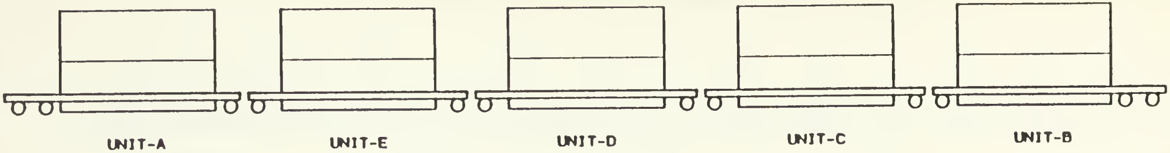
CAR Nos.	CAR CLASS	LOAD LIMIT PER WELL	[illegible]					[illegible]
			[illegible] UNIT	[illegible] UNIT	[illegible] UNIT	[illegible] UNIT	[illegible] UNIT	ALL UNITS
73000-73044	GWG52	124000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
73045-73084	GWG52A	122000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
◆ 73085-73118	GWG52B	117000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
73119-73158	GWG52	124000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
◆ ◆ 73159-73248	GWG52B	117000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
◆ ◆ 73249	GWG52A	122000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
◆ ◆ 73250-73274	GWG52B	117000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

◆ IN PRODUCTION - 73105-73118 NOT BUILT AS OF 5-1-89

◆ ◆ ON ORDER - NONE BUILT AS OF 5-1-89

DTTX

DOUBLE STACK CONTAINER CAR - IBC TYPE
(THRALL 125-TON DESIGN)



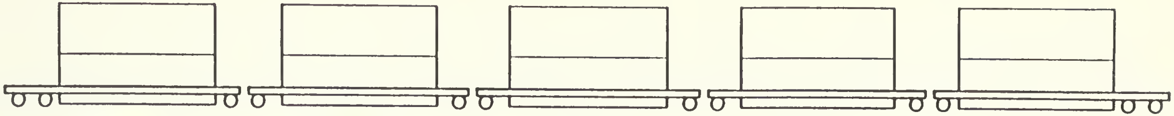
DTTX CAR Nos.	CAR CLASS	LOAD LIMIT PER WELL	LOWER POSITION WELL CAPABILITIES					UPPER POSITION WELL CAPABILITIES
			"A" UNIT	"E" UNIT	"D" UNIT	"C" UNIT	"B" UNIT	ALL UNITS
72000-72151	TWG52	120500	2-20's or 1-40'	40' 45' or 48'	40' 45' or 48'	40' 45' or 48'	2-20's or 1-40'	40', 45', 48' or 53'
72152-72181	TWG52A	120500	40' 45' or 48'	40' 45' or 48'	40' 45' or 48'	40' 45' or 48'	40' 45' or 48'	40', 48', 48' or 53'
72182-72321	TWG52	120500	2-20's or 1-40'	40' 45' or 48'	40' 45' or 48'	40' 45' or 48'	2-20's or 1-40'	40', 45', 48' or 53'
◆ 72322-72381	TWG52B	117000	2-20's or 1-40' or 1-45' or 1-48'	2-20's or 1-40' or 1-45' or 1-48'	2-20's or 1-40' or 1-45' or 1-48'	2-20's or 1-40' or 1-45' or 1-48'	2-20's or 1-40' or 1-45' or 1-48'	40', 45', 48' or 53'

◆ ON ORDER-NONE BUILT AS OF 5-1-89

LOADING CAPABILITIES

DTTX

DOUBLE STACK CONTAINER CAR-IBC TYPE
(THRALL 100-TON DESIGN)



CAR Nos.	CAR CLASS	LOAD LIMIT PER WELL	LOWER POSITION WELL CAPABILITIES					UPPER POSITION WELL CAPABILITIES
			"A" UNIT	"E" UNIT	"D" UNIT	"C" UNIT	"B" UNIT	ALL UNITS
62000-62119	TWG5M	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62120-62139	TWG50A	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62140-62179	TWG50B	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62180-62199	TWG50D	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62200-62239	TWG50E	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62240-62249	TWG50C	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62250-62259	TWG50B	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62260-62262	TWG50C	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62263-62287	TWG50F	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62288-62383	TWG50G	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

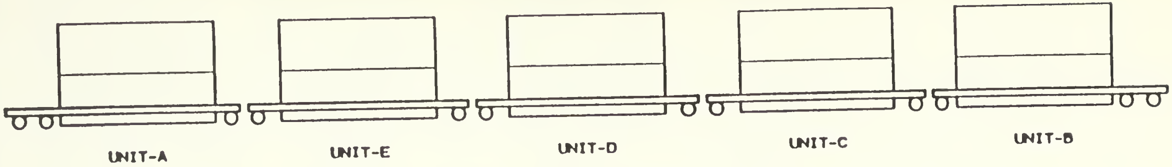
CAR Nos.	CAR CLASS	LOAD LIMIT PER WELL						UPPER POSITION WELL CAPABILITIES
			"A" UNIT	"E" UNIT	"D" UNIT	UNIT	UNIT	ALL UNITS
62384-62399	TWG50B	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62400-62443	TWG50G	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62444-62467	TWG50H	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62468-62542	TWG50G	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62543-62545	TWG50J	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62546-62565	TWG50H	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62576-62728	TWG50K	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62729-62768	TWG50L	102000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
◆ 62566-62570	TWG51	92500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
◆ 62571-62575	TWG51	92500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

◆ BULKHEAD TYPE CAR - NO IBC REQUIRED

B-6667

DTTX

DOUBLE STACK CONTAINER CAR - IBC TYPE
(TRINITY 100-TON AND 125-TON DESIGNS)



100 TON DESIGN								
DTTX CAR Nos.	CAR CLASS	LOAD LIMIT PER WELL	LOWER POSITION WELL CAPABILITIES					UPPER POSITION WELL CAPABILITIES
			"A" UNIT	"E" UNIT	"D" UNIT	"C" UNIT	"B" UNIT	ALL UNITS
64000-64004	RWG50	102000	2-20's or 1-40'	1-40'	1-40'	1-40'	2-20's or 1-40'	40', 45' or 48'
64005-64016	RWG50A	102000	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	40', 45' or 48'
64017-64020	RWG50B	102000	2-20's or 1-40'	1-40'	1-40'	1-40'	2-20's or 1-40'	40', 48' or 48'
64021-64027	RWG50A	102000	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	40', 45' or 48'
64028-64044	RWG50A	102000	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	40', 45' or 48'
64045-64054	RWG50A	102000	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	40', 45' or 48'
64055-64069	RWG50C	102000	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	40', 45' or 48'

125 TON DESIGN								
DTTX CAR Nos.	CAR CLASS	LOAD LIMIT PER WELL	LOWER POSITION WELL CAPABILITIES					UPPER POSITION WELL CAPABILITIES
			"A" UNIT	"E" UNIT	"D" UNIT	"C" UNIT	"B" UNIT	ALL UNITS
◆ 74000-74075	RWG52	122000	2-20's or 1-40'	1-40' 1-45' or 1-48'	1-40' 1-45' or 1-48'	1-40' 1-45' or 1-48'	2-20's or 1-40'	40', 45', 48' or 53'
74076-74080	RWG52A	124000	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	2-20's or 1-40'	40', 45' or 48'
◆ ◆ 74081-74110	RWG52	122000	2-20's or 1-40'	1-40' 1-45' or 1-48'	1-40' 1-45' or 1-48'	1-40' 1-45' or 1-48'	2-20's or 1-40'	40', 45', 48' or 53'

◆ IN PRODUCTION-74049, 74051, 74055 NOT BUILT AS OF 5-1-89
◆ ◆ IN PRODUCTION-74093-74110 NOT BUILT AS OF 5-1-89

B-666

Questions and Summary of Facility Interviews

1. Do you load line or assign cars through the gate?

BN (Seattle): Some aspects of both philosophies.
SP (Oakland): Some aspects of both philosophies.
ATSF (Richmond): Some aspects of both philosophies.
BN (Chicago): Primarily assignment through gate.
NOTE: That no terminal is operated under a pure form of either philosophy

2. Are you able to switch from both ends of the yard?

BN (Seattle): No, but this is perceived as a problem.
SP (Oakland): Yes.
ATSF (Richmond): Yes, but seldom do.
BN (Chicago): Yes, and often do.
NOTE: Being able to switch from both ends of the yard is generally perceived as an advantage.

3. Would more team tracks help?

BN (Seattle): No.
SP (Oakland): Yes.
ATSF (Richmond): No.
BN (Chicago): No.
NOTE: Most terminal operators would like more team tracks, but do not feel expansion is mandatory at current service levels. The SP facility at Oakland is an exception.

4. Would more loaders help?

BN (Seattle): No.
SP (Oakland): No.
ATSF (Richmond): No.
BN (Chicago): No.
NOTE: Most terminal operators would like more loaders, but do not feel they are mandatory at current service levels.

5. Can you expand or are you constrained by other facilities around you?

BN (Seattle): Constrained.
SP (Oakland): Constrained.
ATSF (Richmond): Constrained.
BN (Chicago): Constrained.
NOTE: The SP facility is attempting to negotiate an agreement which would permit expansion.

6. Do you own/control the rail equipment or does a terminal railroad switch for you?

BN (Seattle): Equipment is owned by BN.
SP (Oakland): Equipment is owned by BN.
ATSF (Richmond): Equipment is owned by ATSF.
BN (Chicago): Equipment is owned by BN.

7. What outside influences affect you: Teamsters, Longshoremen, customs, ship arrivals, any others?

BN (Seattle): Those listed, but no others.
SP (Oakland): Those listed, but no others.
ATSF (Richmond): Those listed, but no others.
BN (Chicago): Those listed, but no others.

8. Are train and track dynamics a problem/consideration?

BN (Seattle): Yes.
SP (Oakland): Yes.
ATSF (Richmond): Not discussed.
BN (Chicago): Yes.
NOTE: The BN restrictions delineated in chapter 4 are representative.

9. Do you block your train by destination AT ORIGIN (ie. here)?

BN (Seattle): Yes.
SP (Oakland): Yes.
ATSF (Richmond): Yes.
BN (Chicago): Yes.

10. Do you use air brakes or are all moves handled by hand brake?

BN (Seattle): Use of air brake is mandatory.
SP (Oakland): Use of air brake is mandatory.
ATSF (Richmond): Not discussed.
BN (Chicago): Use of air brake is mandatory.

11. What are your thoughts on the various types of cars around today?

BN (Seattle): Too many different types.
SP (Oakland): Too many different types.
ATSF (Richmond): Too many different types.
BN (Chicago): Not discussed.
NOTE: All terminal operators would like to see more standardization. The more versatile dual purpose cars are the most popular.

12. What are your thoughts on various container sizes?

BN (Seattle): Too many different types.
SP (Oakland): Too many different types.

ATSF (Richmond): Too many different types.
BN (Chicago): Too many different types.
NOTE: All terminal operators would like to see more standardization.

13. Can I get a track diagram of your facility?

BN (Seattle): Yes.
SP (Oakland): No.
ATSF (Richmond): No.
BN (Chicago): Yes.
NOTE: It must be understood that some terminal managers were just to busy to provide a diagram.

14. Can I have a list of daily trains?

BN (Seattle): Yes.
SP (Oakland): No.
ATSF (Richmond): No.
BN (Chicago): Yes.
NOTE: It must be understood that some terminal managers were just to busy to provide such documentation.

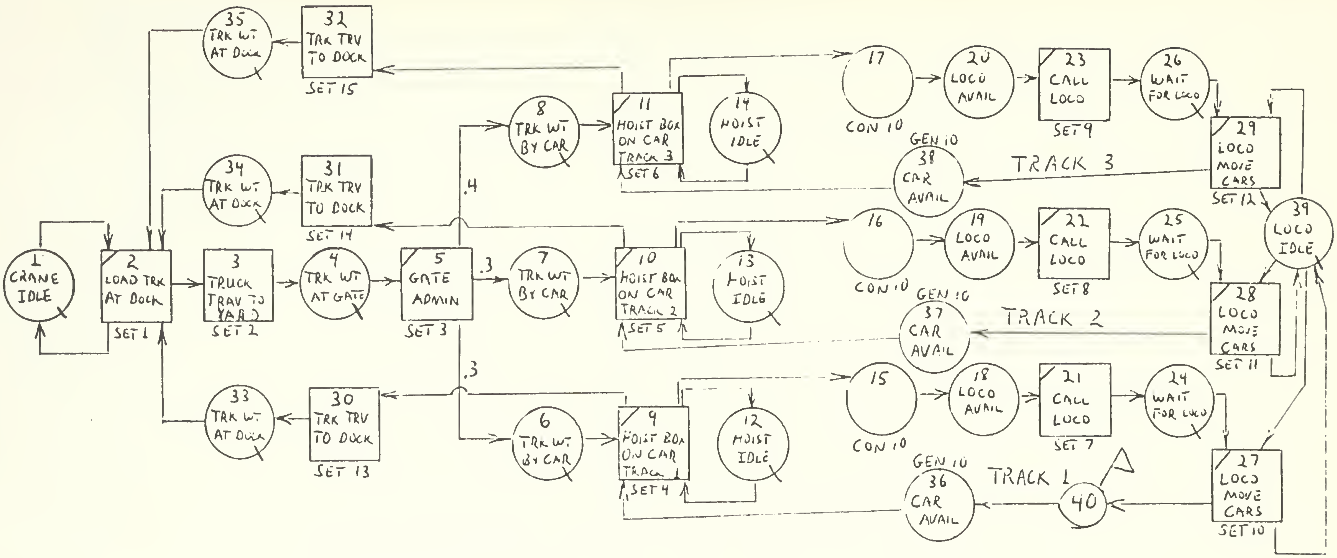
15. Is (or would) on dock rail an advantage?

BN (Seattle): Would be considered an advantage.
SP (Oakland): Not discussed.
ATSF (Richmond): Not discussed. No application at this (inland) facility
BN (Chicago): Discussed, but has no application at this (inland) facility.

```
OCESS: BOXTRAIN
-------------------------------------------------------------------------------
                                   ***  NETWORK FILE  ***
-------------------------------------------------------------------------------
NE    1 :  NAME 'BOXTRAIN' LENGHT 160 CYCLE 20
NE    2 :  NETWORK INPUT
NE    3 :  1 QUEUE 'CRANE IDLE'
NE    4 :  2 COMBI SET 1 'LOAD TRUCK AT DOCK' FOL 1 3 PRE 1 8
NE    5 :  3 NORMAL SET 2 'TRUCK TRAVEL TO DOCK' FOLL 4
NE    6 :  4 QUEUE 'TRUCK WAIT AT GATE'
NE    7 :  5 COMBI SET 3 'LOAD BOX ON CAR' FOL 6 7 9 PRE 4 9 13
NE    8 :  6 FUNCTION CONS 10 FOL 14
NE    9 :  7 NORMAL SET 4 'TRUCK TRAVEL' FOL 8
NE   10 :  8 QUEUE 'TRUCK WAIT AT DOCK'
NE   11 :  9 QUEUE 'HOIST IDLE'
NE   12 :  10 COMBI SET 5 'CALL LOCO' FOL 16 PRE 14
NE   13 :  11 COMBI SET 6 'LOCO MOVE CARS' FOLL 12 15 PRE 15 16
NE   14 :  12 FUN COU FOL 13 QUA 10
NE   15 :  13 QUE 'CARS AVAIL' GEN 10
NE   16 :  15 QUEUE 'LOCO IDLE'
NE   17 :  16 QUEUE 'WAIT FOR LOCO'
NE   18 :  14 QUEUE 'LOCO AVAIL'
NE   19 :  RESOURCE INPUT
NE   20 :  2 'CRANES' AT 1
NE   21 :  10 'TRUCKS' AT 4
NE   22 :  10 'TRUCKS' AT 8
NE   23 :  2 'HOISTS' AT 9
NE   24 :  2 'CARS' AT 13
NE   25 :  2 'LOCOS' AT 15
NE   26 :  2 'CARS' AT 16
NE   27 :  2 'CARS' AT 14
NE   28 :  DURATION INPUT
NE   29 :  SET 1 UNIFORM 1.25 1.75
NE   30 :  SET 2 UNIFORM 2.00 4.00
NE   31 :  SET 3 UNI 1.25 1.75
NE   32 :  SET 4 UNIFORM 2.00 4.00
NE   33 :  SET 5 UNIFORM 10.00 15.00
NE   34 :  SET 6 UNIFORM 20.00 30.00
NE   35 :  ENDDATA
```

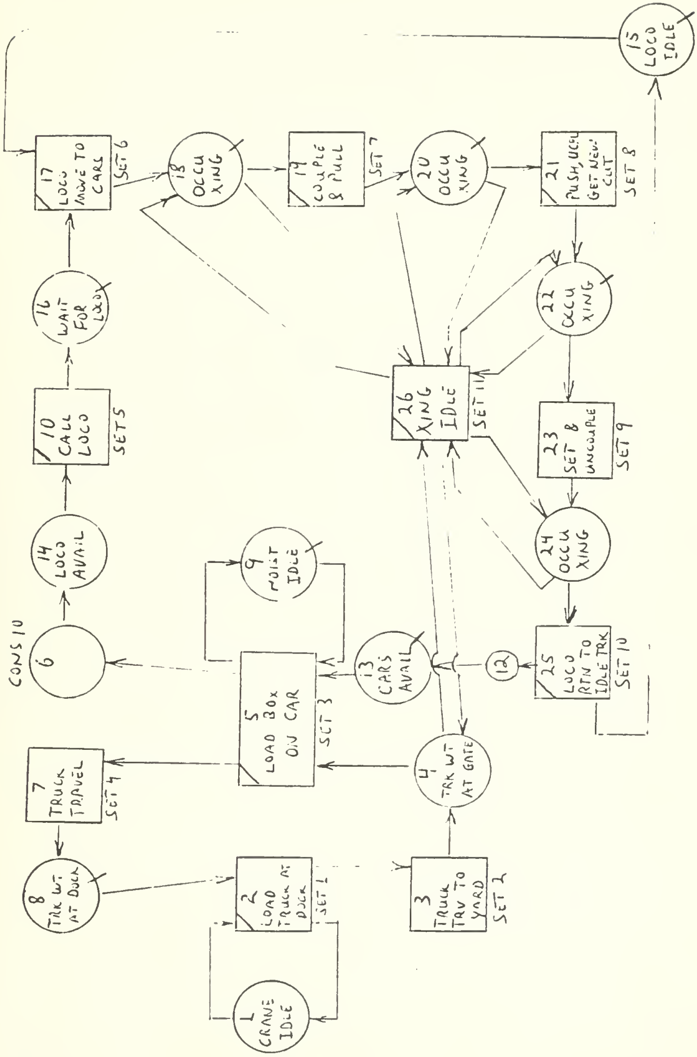
```
35: STRKYRD

                                    *** NETWORK FILE ***

NAME 'STRKYRD' LENGTH 160 CYCLE 20
NETWORK INPUT
1 QUE 'CRANE IDLE'
2 COMBI SET 1 'LOAD TRUCK AT DOCK' FOL 1 3 PRE 1 33 34 35
3 NORMAL SET 2 'TRUCK TRAV TO YARD' FOL 4
4 QUE 'TRUCK WAIT AT GATE'
5 COMBI SET 3 'GATE ADMIN' FOL 6 7 8 PROBABILITY .3 .3 .4 PRE 4
6 QUE 'TRUCK WAIT BY CAR ON TRK ONE'
7 QUE 'TRUCK WAIT BY CAR ON TRK TWO'
8 QUE 'TRUCK WAIT BY CAR ON TRK THREE'
9 COMBI SET 4 'LIFT BOX ON CAR TRK 1' FOL 12 15 30 PRE 6 12 36
10 COMBI SET 5 'LIFT BOX ON CAR TRK 2' FOL 13 16 31 PRE 7 13 37
11 COMBI SET 6 'LIFT BOX ON CAR TRK 3' FOL 14 17 32 PRE 8 14 38
12 QUE 'HOIST IDLE'
13 QUE 'HOIST IDLE'
14 QUE 'HOIST IDLE'
15 FUNCTION CONS 10 FOL 18
16 FUNCTION CONS 10 FOL 19
17 FUNCTION CONS 10 FOL 20
18 QUE 'LOCO AVAIL'
19 QUE 'LOCO AVAIL'
20 QUE 'LOCO AVAIL'
21 COMBI SET 7 'CALL LOCO' FOL 24 PRE 18
22 COMBI SET 8 'CALL LOCO' FOL 25 PRE 19
23 COMBI SET 9 'CALL LOCO' FOL 26 PRE 20
24 QUE 'WAIT FOR LOCO'
25 QUE 'WAIT FOR LOCO'
26 QUE 'WAIT FOR LOCO'
27 COMBI SET 10 'LOCO MOVES CARS' FOL 39 40 PRE 24 39
28 COMBI SET 11 'LOCO MOVES CARS' FOL 37 39 PRE 25 39
29 COMBI SET 12 'LOCO MOVES CARS' FOL 38 39 PRE 26 39
30 NORMAL SET 13 'TRUCK TRAV TO DOCK' FOL 33
31 NORMAL SET 14 'TRUCK TRAV TO DOCK' FOL 34
32 NORMAL SET 15 'TRUCK TRAV TO DOCK' FOL 35
33 QUE 'TRUCK WAIT AT DOCK'
34 QUE 'TRUCK WAIT AT DOCK'
35 QUE 'TRUCK WAIT AT DOCK'
36 QUE 'CAR AVAIL' GEN 10
37 QUE 'CAR AVAIL' GEN 10
38 QUE 'CAR AVAIL' GEN 10
39 QUE 'LOCO IDLE'
40 FUN COU FOL 36 QUA 10
RESOURCE INPUT
2 'CRANES' AT 1
10 'TRUCKS' AT 4
10 'TRUCKS' AT 6
10 'TRUCKS' AT 7
10 'TRUCKS' AT 8
2 'HOISTS' AT 12
2 'HOISTS' AT 13
```

```
INE   51 :  2 'HOISTS' AT 14
INE   52 :  2 'CARS' AT 18
INE   53 :  2 'CARS' AT 19
INE   54 :  2 'CARS' AT 20
INE   55 :  2 'CARS' AT 24
INE   56 :  2 'CARS' AT 25
INE   57 :  2 'CARS' AT 26
INE   58 :  10 'TRUCKS' AT 33
INE   59 :  10 'TRUCKS' AT 34
INE   60 :  10 'TRUCKS' AT 35
INE   61 :  2 'CARS' AT 36
INE   62 :  2 'CARS' AT 37
INE   63 :  2 'CARS' AT 38
INE   64 :  2 'LOCOS' AT 39
INE   65 :  DURATION INPUT
INE   66 :  SET 1 UNI 1.25 1.75
INE   67 :  SET 2 UNI 2.00 4.00
INE   68 :  SET 3 UNI 3.00 5.00
INE   69 :  SET 4 UNI 1.25 1.75
INE   70 :  SET 5 UNI 1.25 1.75
INE   71 :  SET 6 UNI 1.25 1.75
INE   72 :  SET 7 UNI 10.00 15.00
INE   73 :  SET 8 UNI 10.00 15.00
INE   74 :  SET 9 UNI 10.00 15.00
INE   75 :  SET 10 UNI 20.00 30.00
INE   76 :  SET 11 UNI 20.00 30.00
INE   77 :  SET 12 UNI 20.00 30.00
INE   78 :  SET 13 UNI 2.00 4.00
INE   79 :  SET 14 UNI 2.00 4.00
INE   80 :  SET 15 UNI 2.00 4.00
INE   81 :  ENDDATA
```



Network Logic Diagram of Three Track Intermodal Facility

```
OCESS. 1TRNINTR
---------------------------------------------------------------------------------------------------
                                              ***  NETWORK FILE  ***
---------------------------------------------------------------------------------------------------
NE    1 :  NAME '1TRNINTR' LENGTH 160 CYCLE 20
NE    2 :  NETWORK INPUT
NE    3 :  1 QUE 'CRANE IDLE'
NE    4 :  2 COMBI SET 1 'LOAD TRK AT DOCK' FOL 1 3 PRE 1 8
NE    5 :  3 NORMAL SET 2 'TRK TRAV TO DOCK' FOL 4
NE    6 :  4 QUE 'TRK WAIT AT GATE'
NE    7 :  5 COMBI SET 3 'LOAD BOX ON CAR' FOL 6 7 9 PRE 4 9 13
NE    8 :  6 FUNCTION CONS 10 FOL 14
NE    9 :  7 NORMAL SET 4 'TRK TRAV' FOL 8
NE   10 :  8 QUE 'TRK WAIT AT DOCK'
NE   11 :  9 QUE 'HOIST IDLE'
NE   12 :  10 COMBI SET 5 'CALL LOCO' FOL 16 PRE 14
NE   13 :  12 FUN COU FOL 13 QUA 10
NE   14 :  13 QUE 'CARS AVAIL' GEN 10
NE   15 :  15 QUE 'LOCO IDLE'
NE   16 :  16 QUE 'WAIT FOR LOCO'
NE   17 :  14 QUE 'LOCO AVAIL'
NE   18 :  17 COMBI SET 6 'LOCO MOVE TO CARS' FOLL 18 PRE 15 16
INE  19 :  18 QUE 'OCCU XING'
NE   20 :  19 COMBI SET 7 'COUPLE & PULL' FOLL 20 PRE 18
INE  21 :  20 QUE 'OCCU XING'
NE   22 :  21 COMBI SET 8 'PUSH UCPL CPL TO NEW CUT' FOL 22 PRE 20
INE  23 :  22 QUE 'OCCU XING
NE   24 :  23 COMBI SET 9 'SET & UNCPL' FOL 24 PRE 22
INE  25 :  24 QUE 'OCCU XING'
NE   26 :  25 COMBI SET 10 'LOCO RTN TO IDLE TRK' FOL 12 15 PRE 24
INE  27 :  26 COMBI SET 11 'XING IDLE' FOL 4 18 20 22 24 PRE 4 18 20 22 24
NE   28 :  RESOURCE INPUT
INE  29 :  2 'CRANES' AT 1
NE   30 :  10 'TRUCKS' AT 4
NE   31 :  10 'TRUCKS' AT 8
NE   32 :  2 'HOISTS' AT 9
INE  33 :  7 'CARS' AT 13
NE   34 :  2 'LOCOS' AT 15
INE  35 :  2 'CARS' AT 16
NE   36 :  2 'CARS' AT 14
INE  37 :  DURATION INPUT
NE   38 :  SET 1 UNI 1.25 1.75
INE  39 :  SET 2 UNI 2.00 4.00
NE   40 :  SET 3 UNI 1.25 1.75
INE  41 :  SET 4 UNI 2.00 4.00
NE   42 :  SET 5 UNI 10.00 15.00
INE  43 :  SET 6 UNI 3.00 7.00
NE   44 :  SET 7 UNI 3.00 7.00
INE  45 :  SET 8 UNI 3.00 7.00
NE   46 :  SET 9 UNI 3.00 7.00
INE  47 :  SET 10 UNI 3.00 7.00
NE   48 :  SET 11 UNI 10.00 20.00
INE  49 :  ENDDATA
```



Network Logic Diagram of Single Track Facility with Truck Entrance Interdiction

617-586

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